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(54) **Unsaturated urea polysiloxanes.**

(57) New styrene-functional polysiloxanes are described which are obtained by reaction of aminoalkyl functional polysiloxanes with styrene isocyanates. The styrene functional urea polysiloxanes have improved hydrolytic stability and are useful, either by themselves or in combination with copolymerizable comonomers, in UV- or heat curable biocompatible and oxygen permeable coatings, films or shaped articles, especially in form of oxygen permeable contact lenses.

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Di- or poly-vinyl functional polymeric compounds, of about 400 to about 10,000 MW, hereinafter called macromers, are known for a long time and are widely used to make UV-curable coatings, films or crosslinked polymeric articles. Typically these compounds are prepared from low molecular weight polyester- or polyether diols by esterification with acrylic or methacrylic acid, or maleic anhydride; alternatively, they can be more easily prepared by first reacting those polyester- or polyether diols with 2 equivalents of a diisocyanate followed by endcapping with, for instance, 2-hydroxyethyl-methacrylate; such poly-urethane-macromers are described, for instance in US-A-3,509,234 and US-A-4, 192,827.

An even simpler route to essentially similar urethane-macromers is via the reaction of poly-ester- or poly-ether diols with isocyanate-substituted vinyl monomers, typically a methacrylate such as 2-isocyanatoethyl methacrylate (IEM); relevant patents describing such macromers are US-A-4,233,425 and US-A-4,320,221.

The macromer approach has also been applied to polysiloxane (PDMS) dialkanols and PDMS-dialkanol-bis methacrylates are even commercially available. Both urethane based macromer types have also been described, for instance in US-A-4,136,250, US-A-4,130,708 and US-A-4,486,577.

In all instances the linking group between the PDMS-chain and the easily polymerizable vinyl group contains an ester linkage, contributed either by the hydroxyalkyl- or aminoalkyl methacrylate used in the capping reaction, or by 2-isocyanatoethyl methacrylate. However, this ester linkage constitutes a weakness, if great hydrophilic stability is a requirement, as for example in a PDMS-containing hydrogel.

US-A-4,837,289 discloses PDMS-tetraalkanols capped with m-isopropenyl- $\alpha,\alpha$ -dimethyl-benzylisocyanate (TMI), thus providing an ester free linkage group. TMI is a commercially available compound (American Cyanamid) and has been used in a variety of applications, for instance: in the preparation of vinyl-diols (Polym. Mater. Sci. Eng., 57, 565 (1987); in the preparation of macromer for adhesives, by reaction with polyols, for instances poly-tetramethylene ether glycol (FR-A1-2,579,611); in high-solids coatings after reaction of a polyester polyol, as described in US-A-4,609,706; the reaction of TMI with amines is also disclosed in Polym. Mater. Sci. Eng., 53, 534 (1985).

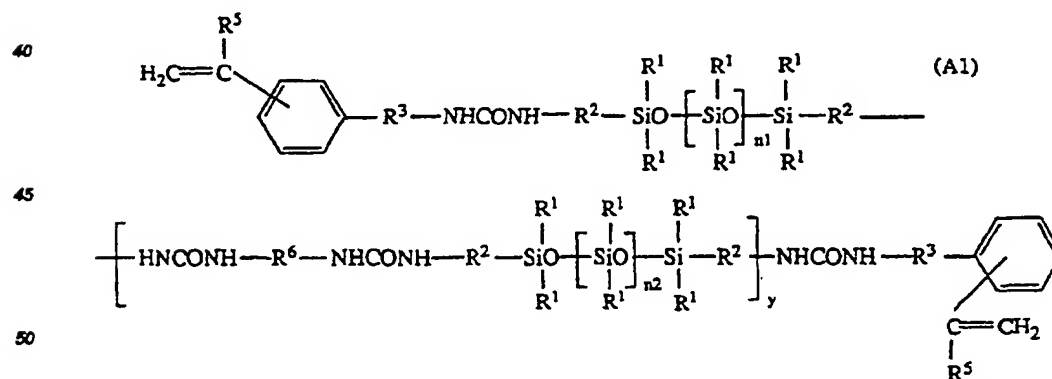
No reaction products of aminoalkyl-substituted polysiloxanes and m-isopropenyl- $\alpha,\alpha$ -dimethylbenzyl isocyanate have been described, although the reaction of products of aminoalkyl-substituted PDMS and 2-isocyanatoethyl methacrylate are described in US-A-4,563,539 and US-A-4,605,712.

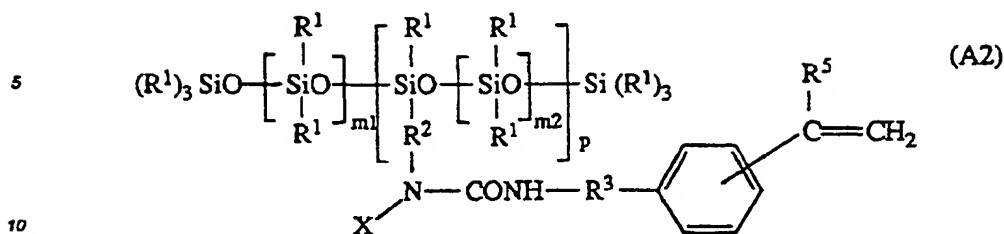
It has now been discovered that by reaction of poly-(aminoalkyl)-polysiloxane with m-isopropenyl- $\alpha,\alpha$ -dimethylbenzyl isocyanate, or any similar styrenic isocyanate, a PDMS-macromer can readily be prepared, which results in superior properties when incorporated into rigid, oxygen permeable polymers or into hydrogels.

It is an object of this invention to provide an easily polymerizable, hydrolytically stable and rigidity imparting urea-polysiloxane macromer.

It is a further object of this invention to make improved rigid, oxygen permeable contact lenses and oxygen permeable hydrogels by copolymerization of said urea-polysiloxane macromer with vinyl monomers.

The novel polysiloxane-urea styrenic macromers are of the general structures A1 or A2:





wherein, independently of each other,

R<sup>1</sup> is methyl, phenyl or 3,3,3-trifluoropropyl,

15 R<sup>2</sup> is a divalent saturated linear or branched hydrocarbon radical having 1 to 6 carbon atoms,

R<sup>3</sup> is a direct bond or has the same definition as R<sup>2</sup>,

R<sup>5</sup> is hydrogen or methyl,

R<sup>6</sup> is the divalent residue of an aliphatic, cycloaliphatic or aromatic diisocyanate of structure  
OCN-R<sup>6</sup>-NCO,

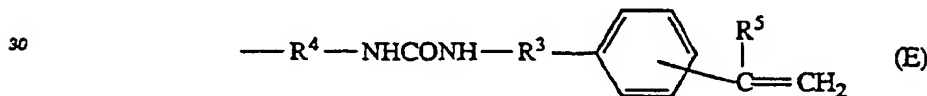
20 n<sub>1</sub> and n<sub>2</sub> are integers from 2 to 250, preferably 10 to 50, more preferred 10 to 20, with the proviso that the sum n<sub>1</sub> + n<sub>2</sub> is not greater than 250,

m<sub>1</sub> and m<sub>2</sub> are integers from 2 to 200, preferably 5 to 100, with the proviso that the sum m<sub>1</sub> + m<sub>2</sub> is not greater than 250,

y is 0 to 2,

25 p has a value of 1 to 10, preferably 1 to 3,

X is hydrogen or has the structure E:



wherein R<sup>4</sup> is a divalent saturated linear or branched hydrocarbon radical havin 1 to 6 carbon atoms.

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Preferably, a divalent saturated linear or branched hydrocarbon radical of from 1-6 carbon atoms is C<sub>1</sub>-C<sub>6</sub> alkylene, such as methylene, ethylene, propylene, or butylene, e.g. 1,3-propylene or 2,2-propylene.

The divalent residue of an aliphatic, cycloaliphatic or aromatic diisocyanate preferably is an aliphatic or aromatic divalent residue with 6 to 12 carbon atoms. Preferably these residues are divalent phenylene-C<sub>1</sub>-C<sub>4</sub>-alkylene residues unsubstituted or substituted by C<sub>1</sub>-C<sub>4</sub>-alkyl, phenylene unsubstituted or substituted by C<sub>1</sub>-C<sub>4</sub>-alkyl or C<sub>1</sub>-C<sub>7</sub>-alkylene unsubstituted or substituted by C<sub>1</sub>-C<sub>4</sub>-alkyl.

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Preferred are macromers of structure A1, in which

R<sup>1</sup> is methyl,

R<sup>2</sup> is trimethylene,

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R<sup>3</sup> is -C(CH<sub>3</sub>)<sub>2</sub>-

R<sup>5</sup> is methyl,

y is zero, and

n<sub>1</sub> is 5 to 100.

Also preferred are macromers of structure A1, in which most or all of

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R<sup>1</sup> are methyl,

R<sup>2</sup> is trimethylene,

R<sup>3</sup> is -C(CH<sub>3</sub>)<sub>2</sub>-

R<sup>5</sup> is methyl,

y is 1,

55

n<sub>1</sub> + n<sub>2</sub> is 10 to 20,

and R<sup>6</sup> is an aliphatic or aromatic divalent residue with 6 to 12 carbon atoms.

Also preferred are macromers of structure A2, wherein most or all of  
R<sup>1</sup> are methyl,

R<sup>2</sup> is trimethylene,

R<sup>3</sup> is -C(CH<sub>3</sub>)<sub>2</sub>-

R<sup>6</sup> is methyl,

X is of structure E,

5 R<sup>4</sup> is ethylene,

m<sub>1</sub> and m<sub>2</sub> are 5 to 100, with the sum m<sub>1</sub> + m<sub>2</sub> not greater than 150,

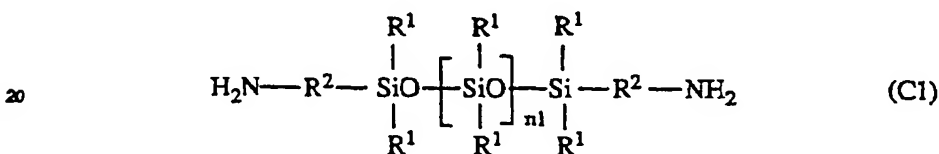
and p is 1 to 3.

Also preferred are macromers wherein R<sup>3</sup> is a direct bond and R<sup>6</sup> is hydrogen with the -CR<sup>6</sup>=CH<sub>2</sub> group being in the para position relevant to R<sup>3</sup>; or wherein R<sup>3</sup> is -C(CH<sub>3</sub>)<sub>2</sub>- and R<sup>6</sup> is methyl with the -CR<sup>6</sup>=CH<sub>2</sub> group being in the meta position relevant to R<sup>3</sup>.

Most preferred are macromers of structure A1, wherein R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup> and R<sup>6</sup> are as defined as for the preferred A1 macromer, and n<sub>1</sub> is 10 to 50.

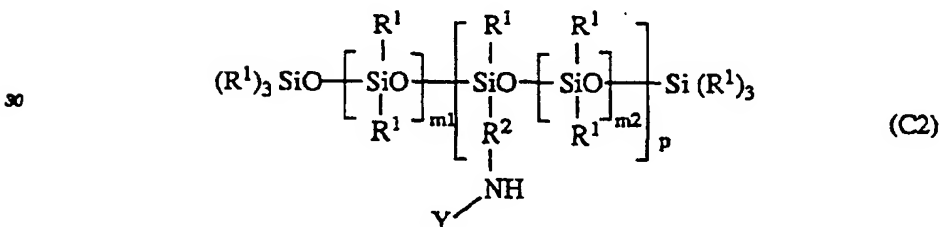
The macromers of the present invention are made by mixing together an aminoalkyl-functional polysiloxane of either structure

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Or

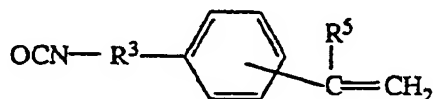
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wherein Y is hydrogen or -R<sup>4</sup>NH<sub>2</sub>, with a styrene-isocyanate of structure

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preferably in equivalent amounts, but less or more of the equivalent amount of the styrene-isocyanate may also be used. The reaction proceeds smoothly, with or without catalyst, and is complete when no NCO-groups are detectable by IR-analysis.

Aminoalkyl substituted polysiloxanes are well known and many are commercially available, both, of structures C1 and C2. Exemplary polysiloxanes of structure C1 are those wherein R<sup>2</sup> is trimethylene and which have molecular weights of 400 to 8000. Exemplary polysiloxanes of structures C2 are those wherein R<sup>2</sup> is trimethylene, Y is -CH<sub>2</sub>CH<sub>2</sub>NH<sub>2</sub> and which have molecular weights of 400 to 8000.

Exemplary styrenic isocyanates are p-isocyanatostyrene and m-isopropenyl-α,α-dimethyl-benzyl isocyanate (TMI).

Diisocyanates useful to form chain extended prepolymer intermediates are aliphatic, cycloaliphatic or aromatic diisocyanates selected from the group consisting of ethylene diisocyanate, 1,2-diisocyanatopropane, 1,3-diisocyanatopropane, 1,6-diisocyanatohexane, 1,2-diisocyanatocyclohexane, 1,3-diisocyanatocyclohexane, 1,4-diisocyanatobenzene; bis-(4-isocyanatophenyl)methane, 1,2- and 1,4-toluene diisocyanate; 3,3'-dichloro-4,4'-diisocyanatobiphenyl; 1,5-diisocyanatonaphthalene, hydrogenated toluene diisocyanate; 1-isocyanatomethyl-5-isocyanato-1,3,3-trimethylcyclohexane (= isophoron diisocyanate); 1,6-diisocyanato-

2,2,4-(2,4,4)-trimethylhexane, 2,2'-diisocyanatodiethyl fumarate; 1,5-diisocyanato-1-carboxyp ntane; 1,2-, 1,3-, 1,6-, 1,7-, 1,8-, 2,7- and 2,3-diisocyanatonaphthalene; 2,4- and 2,7-diisocyanato-1 methylnaphthalene; 1,4-diisocyanato-methylcyclohexane; 1,3- diisocyanato-6(7)-methylnaphthalene; 4,4'-diisocyanatobiphenyl; 4,4'-diisocyanato-3,3'-dimethoxy-biphenyl; 3,3'- and 4,4'-diisocyanato-2,2'-dimethyl-biphenyl; bis-(4-isocyanatophenyl)ethane; bis(4-isocyanato-phenyl) ether.

The most preferred diisocyanates are isophorone diisocyanate, 2,2,4-(2,4,4)-trimethylhexane-1,6-diisocyanate and 1,2- or 1,4-toluene diisocyanate.

The diisocyanates can be used in molar ratios of amino functional polysiloxane:diisocyanate of 100:1 to 4:3.

The reaction can be carried out in bulk or in a suitable aprotic solvent, such as a ketone, ester, amide, or ether, typical solvents are methyl ethyl ketone, methyl propyl ketone, isopropyl acetate, N,N-dimethyl-formamide, dipropylene glycol dimethyl ether, and dimethyl sulfoxide.

Instead of the aforementioned aprotic, nonreactive solvents, aprotic vinyl monomers can also be used as solvents if the final desired polymer is a copolymer of A1 or A2 and a vinyl monomer. If chain extended polysiloxanes are used, they are prepared in a first reaction step by reaction of the diisocyanate with the amino-polysiloxane.

The styrenic unsaturated polysiloxanes can be used by themselves to produce by radiation- or heat-initiated polymerization coatings and films. Preferably though the unsaturated polysiloxanes of the present invention are used in combination with other vinyl monomers to make crosslinked polysiloxane-polyvinyl-block copolymers. Such copolymers are also an object of this invention.

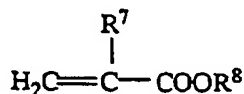
The great variety of monomeric reactants makes it possible to prepare either hard, highly crosslinked copolymers with suitable acrylic, methacrylic or other vinyl monomers, or to prepare soft, rubber-like copolymers with low crosslink density.

It is also possible to prepare by copolymerization with hydrophilic monomers polysiloxane-hydrogels with water contents ranging up to 80%.

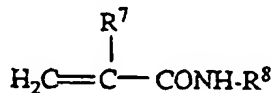
Reactive monomers which can be employed together with the unsaturated polysiloxane include mono- or poly-ethylenically unsaturated monomers which undergo polymerization upon exposure to UV-radiation or by chemical initiation.

If the polyunsaturated polysiloxanes are to be used in biocompatible materials, especially in either hard or soft contact lenses, a balance of hydrophilic and hydrophobic properties is required and water-soluble as well as water-insoluble comonomers can be used.

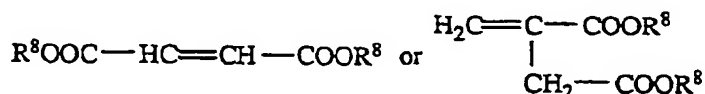
The water-insoluble vinyl monomers (B<sub>1</sub>) useful in the present invention comprise: Acrylates and methacrylates of the general structure:



acrylamides and methacrylamides of structure:



maleates, fumarates and itaconates of structures:



vinyl esters:  $\text{R}^8-\text{COO}-\text{CH}=\text{CH}_2$  and

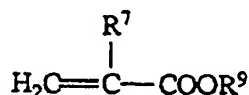
vinyl ethers:  $\text{CH}_2=\text{CH}-\text{O}-\text{R}^8,$

wherein R<sup>7</sup> is hydrogen or methyl, and R<sup>8</sup> is a linear or branched aliphatic, cycl aliphatic or aromatic group with from 1 to 21 carbon atoms, e.g. an alkyl, cycl alkyl or phenyl group, and which may contain ether or thioether linkages or a -CO- group; R<sup>8</sup> may also be a heterocyclic group containing oxygen, sulfur or nitrogen atoms, or a polypropylene oxide or poly-n-butylene oxide group with from 2 to 50 repeating alkoxy units.

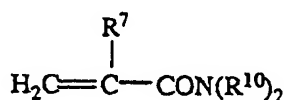
In addition, the R<sup>8</sup> group may contain halogen atoms, especially fluorine in form of perfluorinated alkyl groups with from 1 to 12 carbon atoms; or it may be or contain a siloxane group with from one to six Si atoms; and may contain -SO- and -SO<sub>2</sub> groups. When R<sup>8</sup> is part of a fumarate, maleate or itaconate, one of R<sup>8</sup> may be hydrogen.

Included among the useful monomers are: methyl-; ethyl-; propyl-; isopropyl-; butyl-; isobutyl-; tert-butyl-; ethoxyethyl-; methoxyethyl-; benzyl-; 4-tert-butylphenyl-; cyclohexyl-; trimethylcyclohexyl-; isobornyl-; dicyclopentadienyl-; norbornylmethyl-; cyclododecyl-; 1, 1,3,3-tetramethylbutyl-; n-butyl-; n-octyl-; 2-ethylhexyl-; decyl-; dodecyl-; tridecyl-; octadecyl-; glycidyl-; ethylthioethyl-; furfuryl-; 2-ethoxyethyl, 2-methoxyethyl, 2-butoxyethyl, 2-(2-ethoxyethoxy)ethyl-; hexafluoroisopropyl-; 1, 1,2,2-tetrahydroperfluorododecyl-; tri-, tetra- or penta-siloxanyl silyl propylacrylates and methacrylates, especially tris(trimethylsiloxy) silyl-propyl methacrylate, as well as the corresponding amides; N-(1,1-dimethyl-3-oxobutyl)-acrylamide; mono- and dimethyl fumarate, maleate and itaconate; diethyl fumarate; isopropyl and diisopropyl fumarate and itaconate; mono- and diphenyl and methyl-phenyl fumarate and itaconate; methyl vinyl ether and methoxyethyl vinyl ether; vinyl acetate, vinyl propionate, vinyl benzoate, acrylonitrile, styrene, alpha-methyl styrene and tert-butylstyrene.

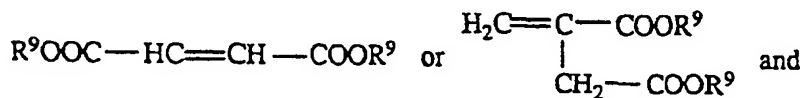
Water-soluble monomers (B<sub>2</sub>) which are also useful comonomers in the present invention comprise acrylates and methacrylates of the general structure:



Acrylamides and methacrylamides of structure



Maleates and fumarates; or itaconates of structures:



vinyl ethers of structure:  $\text{CH}_2=\text{CH}-\text{O}-\text{R}^9$ ,

wherein R<sup>9</sup> is a hydrocarbon residue of 1 to 10 carbon atoms substituted by one or more water solubilizing groups such as carboxy, hydroxy or tert-amino, or a polyethylene oxide group with from 2-100 repeating units, or a group which contains sulfate, phosphate, sulfonate or phosphonate groups; R<sup>7</sup> is hydrogen or methyl and wherein R<sup>10</sup> is independently hydrogen or an alkyl group with 1 to 4 carbon atoms; likewise useful as comonomers are also N-vinyl-lactams, like N-vinyl-2-pyrrolidone.

Included among the useful water soluble monomers are: 2-hydroxyethyl-; 2- and 3-hydroxypropyl-, 2,3-dihydroxypropyl-; poly-ethoxyethyl-; and polyethoxypropylacrylates and methacrylates as well as the corresponding acrylamides and methacrylamides. Sucrose-, mannose-, glucose-, sorbitol acrylates and methacrylates; and di-(2-hydroxyethyl) maleate; acrylamide and methacrylamide, N-methylacrylamide and methacrylamide, bisacetone-acrylamide; N-(2-hydroxyethyl)acrylamide; N,N-dimethyl-acrylamide and -methacrylamide; methylol acrylamide and -methacrylamide; N-vinylformamide and N-vinylacetamide; N,N-diethyl- and N,N-diethyl-aminoethyl acrylate and methacrylate as well as the corresponding acrylamides and methacrylamides, N-tert-butylaminoethyl methacrylate and methacrylamide; 2- and 4-vinylpyridine; 4- and 2-

methyl-5-vinylpyridine; N-methyl-4-vinyl piperidine; 1-vinyl- and 2-methyl- 1-vinylimidazole; para- and orthoaminostyrene; dimethylaminoethyl vinyl ether, N-vinylpyrrolidone; 2-pyrrolidinoethyl methacrylate; acrylic and methacrylic acid; itaconic, cinnamic-, crotonic-, fumaric-, and maleic acids and lower hydroxyalkyl mono- and diesters thereof, such as 2-hydroxyethyl- and di(2-hydroxy)ethyl fumarate, maleate and itaconate, and 3-hydroxypropyl butyl fumarate, and di-(polyalkoxy)alkyl-fumarates, maleates and itaconates; maleic-anhydride; sodium acrylate and methacrylate, 2-methacryloyloxyethylsulfonic acid, 2-acrylamido-2-methyl-propanesulfonic acid, 2-phosphatoethyl methacrylate, vinylsulfonic acid, sodium vinylsulfonate, p-styrenesulfonic acid, sodium p-styrenesulfonate, and allylsulfonic acid.

Also included are the quaternized derivatives of cationic monomers obtained by quaternization with selected alkylating agents like halogenated hydrocarbons such as methyl iodide, benzyl chloride or hexadecyl chloride; epoxides like glycidol, epichlorohydrin, ethylene oxide; dimethyl sulfate; methyl sulfate; propane sulfone.

Preferred monomers for making hard polymers are, in amount of 10 to 90% (w/w): methyl methacrylate, cyclohexyl methacrylate, trimethylcyclohexyl methacrylate, isobornyl methacrylate, isopropyl methacrylate, isobutyl methacrylate, tert.-butyl methacrylate; trifluoroethyl methacrylate, hexafluoroisopropyl methacrylate, or 1,1-dihydroheptafluorobutyl methacrylate; styrene, tert.-butylstyrene, or mixtures thereof, and tris-(trimethylsiloxy)silylpropyl methacrylate.

For soft polymers the preferred monomers are: methyl acrylate; 2-ethylhexyl acrylate, n-butyl acrylate, n-butyl methacrylate, n-octyl acrylate, 2-ethoxyethyl acrylate, 2-methoxy-ethyl acrylate and methacrylate, tris-(trimethylsiloxy)silylpropyl methacrylate and  $R_1$  alkylene acrylate and methacrylate, where  $R_1$  is a perfluoroalkyl group with 1 to 20 carbon atoms and alkylene is  $C_1$ - $C_4$ -alkylene. Preferred comonomers for making hydrogels are: 2-hydroxyethyl methacrylate; 2-hydroxyethyl acrylate; N,N-dimethylacrylamide; acrylic and methacrylic acid, N-vinyl-2-pyrrolidone or mixtures thereof.

A wide range of polyvinyl compounds ( $B_3$ ) can be used in addition to the monovinyl compounds. Indeed, from 0 to 50% by weight of the total monomer can be e.g. a di- or triolefinic monomer, for example:

Allyl acrylate and methacrylate, ethylene glycol-, diethylene glycol-, triethylene glycol-, tetraethylene glycol-, and generally polyethylene oxide glycol diacrylates and dimethacrylates; 1,4-butanediol and poly-n-butylene oxide glycol diacrylates and dimethacrylates; propylene glycol and polypropylene oxide glycol diacrylates and dimethacrylates; thiodiethylene glycol diacrylate and dimethacrylate; neopentylene glycol diacrylate and dimethacrylate; trimethylolpropane tri- and tetraacrylate; pentaerythritol tri- and tetraacrylate; divinylbenzene; divinyl ether, divinyl sulfone; 1,3-bis (3-methacryloxy propyl) tetramethyl disiloxane, 1,3-bis (3-methacryloxypropyl) tetra (trimethylsiloxy) disiloxane and the corresponding acrylates; bisphenol A diacrylate or dimethacrylate; methylene bisacrylamide or methacrylamide, dimethylene bisacrylamide or methacrylamide; N,N'-dihydroxyethylene bisacrylamide or methacrylamide; hexamethylene bisacrylamide or methacrylamide; decamethylene bisacrylamide or methacrylamide; allyl- and diallyl maleate, triallyl melamine, diallyl itaconate, diallyl phthalate, triallyl phosphite, polyallyl sucrose, sucrose diacrylate, glucose dimethacrylate; also, unsaturated polyesters, such as poly-(alkylene-glycol maleates) and poly(alkylene-glycol fumarates), like poly(propylene glycol maleate) and poly(polyalkyleneoxide glycol maleate).

Macromeric divinyl compounds can also be used for copolymerization like polyethylene oxide dimethacrylates, polytetraethylene oxide dimethacrylates (US-A-4,192,827) or polysiloxane dimethacrylates, (US-A-4,605,712) or perfluoroether dimethacrylates.

The polyvinyl-polysiloxanes of this invention are used either by themselves or together with the mentioned comonomers to make oxygen permeable polymers in a last synthesis step by free radical copolymerization, either in bulk or in the presence of small amounts of solvents. The polymerization is suitably carried out with a free radical generating initiator at a temperature in the range from about 40°C to about 105°C, the preferred temperature ranges being between about 50°C and about 100°C. These initiators are preferably peroxides or azo catalysts having a half-life at the polymerization temperature of at least 20 minutes. Typical useful peroxy compounds include: isopropyl percarbonate, tert.-butyl percarbonate, benzoyl peroxide, lauryl peroxide, decanoyl peroxide, acetyl peroxide, succinic acid peroxide, methyl ethyl ketone peroxide, tert.-butyl peroxyacetate, pelargonyl 2,5-dimethyl-2,5-bis(2-ethyl-hexanoylperoxy) hexane, p-chlorobenzoyl peroxide, tert.-butylperoxy-butyrate, tert.-butyl peroxy-maleic acid, tert.-butylperoxy-isopropyl carbonate, bis(1-hydroxy-cyclohexyl) peroxide; azo compounds including 2,2'-azo-bisisobutyronitrile; 2,2'-azo-bis-(2,4-dimethylvaleronitrile); 1,1'-azo-bis(cyclohexane carbonitrile), 2,2'-azo-bis(2,4-dimethyl-4-methoxy-valeronitrile).

Other free radical generating mechanisms can be employed, such as X-rays, electron-beams and UV-radiation. Preparation of contact-lens blanks by UV radiation in the presence of a photo-initiator such as diethoxyacetophenone, 1-hydroxycyclohexyl phenylketone, 2,2-dimethoxy-2-phenylacetophenone, phenothiazine, diisopropylxanthogen disulfide, benzoin and benzoin derivatives is a preferred method.

The amount of initiator can vary from 0.002% to 1% by weight of the monomer and macromer, but is preferred

erably from 0.03 to 0.3% by weight thereof.

A preferred laboratory method of preparing the polymer, in the form of a cylinder, comprises the filling of flexible polymer tubing with the preferred composition of macromer, monomers, and catalyst and reacting the mixture for approximately 2 hours at 80°C. The finished article is removed by slitting the tubing longitudinally and stripping it away from the polymer article.

Another preferred method for preparing the polymer is by radiation with ultraviolet light in the presence of a photo-initiator and using plastic molds which are UV transparent, such as molds made of polypropylene or other UV-permeable plastics, or by making coatings and films by UV-curing.

The polymerization is preferably carried out in an inert atmosphere if done in open molds. It is known that oxygen inhibits polymerization and gives rise to extended polymerization times. If closed molds are used to form the article, the molds are composed of inert materials having low oxygen permeability and non-stick properties. Examples of suitable molding materials are poly(tetrafluoroethylene), such as TEFLON®, silicone rubber, polyethylene, polypropylene and polyester, such as MYLAR®. Glass and metallic molds may be used if a suitable mold-releasing agent is employed.

The instant invention also relates to a polymer, suitable as a biocompatible, oxygen permeable polymer, especially for use in contact lenses, comprising the crosslinked copolymerization product of

(A) from about 10 to about 100% by weight of said polymer of a polysiloxane macromer of formula A1 or A2 having a molecular weight from about 400 to about 10,000, said macromer containing at least two terminal polymerizable olefinic groups, said groups being attached to the polysiloxane through a urea linkage, and

(B) from 90% to 0% by weight of said polymer of one or more mono-, di- or trifunctional vinyl monomers polymerizable by free radical polymerization.

More particularly, the instant invention relates to a polymer, suitable for use in contact lenses, comprising the crosslinked copolymerization product of

(A) from about 15 to about 90% by weight of said polymer of a polysiloxane macromer having a molecular weight from about 800 to about 10,000, said macromer containing two terminal, polymerizable olefinic groups, said macromer having the structure of formula A1 or A2 and

(B) from about 85 to about 10 % by weight of said polymer of water-soluble or water-insoluble monomers or mixtures thereof, said monomers being monoolefinic, diolefinic or a mixture of monoolefinic and diolefinic monomers.

The polymers of this invention can be tailored so as to be useful either as hard contact lens material or as soft contact lens material. Different comonomers and different levels of polysiloxane macromer are required to get optimal performance in either contact lens type.

In choosing the polysiloxane component and the vinyl monomer for a hard contact lens composition, it is important to arrive at a mixture which will give clear polymers with sufficient dimensional stability and oxygen permeability. Sometimes a mixture of comonomers is advantageous in avoiding phase-separation and thereby opacity. Also, it is easier to obtain clear products with polysiloxanes of relatively low molecular weight than with high molecular weight polysiloxanes. Polysiloxanes with a short chain length between crosslinks also give harder, more dimensionally stable polymers; however, their oxygen permeability is reduced compared to polysiloxanes with longer chain length and therefore lower crosslink density. By a judicious choice of monomer(s) and polysiloxane macromer, one is thus able to tailor to a considerable degree the physical properties and oxygen permeability of the instant silicone polymers, from hard and rigid to rubbery and soft. In addition to hard and soft contact lenses, because of their good tissue compatibility and oxygen permeability and strength and elasticity, the polymers of the present invention are also particularly suitable for use as intramuscular and subcutaneous implants in warm-blooded animals. For the same reasons, the materials of the present invention may be fashioned into substitute blood vessels or extra-corporeal shunts.

For preparing hard contact lenses, the preferred polymer comprises the crosslinked copolymerization product of (A) from 15 to 80% of a polysiloxane macromer of formula A1 or A2, and (B) from 85 to 20% by weight of a mixture of comonomers of which, based on the total weight of comonomers, (B<sub>1</sub>) is 100 to 65% by weight of a water-insoluble monoolefinic monomers or mixtures thereof, (B<sub>2</sub>) is 0 to 35% by weight of a water-soluble monoolefinic monomer or mixture thereof, and (B<sub>3</sub>) is 0 to 35% by weight of a diolefinic monomer. The preferred water-insoluble monomers are methyl methacrylate, cyclohexyl methacrylate, tris(trimethyl-siloxanyl)silyl-propyl methacrylate, trifluoroethyl methacrylate, hexafluoroisopropyl methacrylate, 1,1-dihydroheptafluorobutylmethacrylate, trimethylcyclohexyl methacrylate, isobornyl methacrylate, tert.-butyl methacrylate, tert.-butyl-styrene or mixtures thereof. The preferred water-soluble monomers are 2-hydroxyethyl methacrylate, N,N-dimethylacrylamide, acrylic acid, methacrylic acid, maleic anhydride or N-vinyl-2-pyrrolidone or mixtures thereof, and the preferred diolefinic monomers are ethylene glycol dimethacrylate, neopentyl glycol diacrylate or methacrylate, and bis-(3-methacryloxy propyl) tetramethyl disiloxane and bis(3-methacryloxypropyl)



tetra(trimethylsiloxy) disiloxane.

A preferred embodiment of the instant polymers useful for making hard copolymers, for instance for hard contact lenses, is the polymer comprising the copolymerization product of

- (A) 20 to 75% by weight of a polysiloxane of formula A1 where R<sup>1</sup> and R<sup>5</sup> are methyl, R<sup>2</sup> is trimethylene, R<sup>3</sup> is -C(CH<sub>3</sub>)<sub>2</sub>-, and n<sub>1</sub> is 10 to 50, and  
 (B) 80 to 25% by weight of a mixture of comonomers of which, based on the total weight of comonomers, is

- (B<sub>1</sub>) 95 to 65% by weight of a water-insoluble monoolefinic monomer or mixture thereof, and  
 (B<sub>2</sub>) 5 to 35% by weight of a water-soluble monoolefinic monomer or mixture thereof.

Another preferred embodiment of the instant polymers useful for making hard copolymers, for instance hard contact lenses, is the polymer comprising the copolymerization product of

- (A) 20 to 75% by weight of a polysiloxane of formula A1 where R<sup>1</sup> and R<sup>5</sup> are methyl, R<sup>2</sup> is trimethylene, R<sup>3</sup> is -C(CH<sub>3</sub>)<sub>2</sub>-, n<sub>1</sub> is 10 to 50, y is 1, and R<sup>6</sup> is the divalent residue of isophorone diisocyanate; 2,2,4-(2,4,4)-trimethylhexane-1,6-diisocyanate or toluene diisocyanate; and  
 (B) 80 to 25% by weight of comonomers of which, based on the total weight of comonomers, is  
 (B<sub>1</sub>) 95 to 65% by weight of a water-insoluble monoolefinic monomer or mixture thereof,  
 (B<sub>2</sub>) 5 to 35% by weight of a water-soluble monoolefinic monomer or mixture thereof, and  
 (B<sub>3</sub>) 0 to 20% by weight of a diolefinic monomer.

A still more preferred embodiment of the instant polymer comprises the copolymerization product of

- (A) 20 to 75% by weight of a polysiloxane of formula A1 where R<sup>1</sup> is methyl, and  
 (B) 25 to 80% by weight of a mixture of comonomers of which, based on the total weight of comonomers, is

- (B<sub>1</sub>) 95 to 65 % by weight of a monomer selected from the group consisting of methyl methacrylate, cyclohexyl methacrylate, trimethylcyclohexyl methacrylate, isobornyl methacrylate, 2,2,2-trifluoroethyl methacrylate, hexafluoroisopropyl methacrylate, 1,1-dihydroheptafluorobutyl methacrylate, tris(trimethylsiloxy-silyl)propyl methacrylate, tert-butyl methacrylate, styrene and tert-butylstyrene,  
 (B<sub>2</sub>) 5 to 35% by weight of a monomer selected from the group consisting of acrylic acid, methacrylic acid, N,N-dimethylacrylamide, and maleic anhydride,  
 (B<sub>3</sub>) 0 to 20% by weight of ethylene glycol dimethacrylate, neopentyl glycol diacrylate, or bis-(3-methacryloxypropyl)-tetramethyl-disiloxane.

Another preferred embodiment of the instant polymers comprises the copolymerization product of

- (A) 20 to 75% by weight of a polysiloxane of formula A2 where R<sup>1</sup> and R<sup>5</sup> are methyl, R<sup>2</sup> is trimethylene, R<sup>3</sup> is -C(CH<sub>3</sub>)<sub>2</sub>-, X is of structure (E), R<sup>4</sup> is ethylene, n<sub>1</sub> is 10 to 50, p is 1 to 3, and  
 (B) 80 to 25% by weight of a mixture of comonomers of which, based on the total weight of comonomers, is

- (B<sub>1</sub>) 95 to 65% by weight of a monomer selected from the group consisting of methyl methacrylate, cyclohexyl methacrylate, trimethylcyclohexyl methacrylate, isobornyl methacrylate, 2,2,2-trifluoroethyl methacrylate, hexafluoroisopropyl methacrylate, 1,1-dihydro-heptafluorobutyl methacrylate, tert-butyl methacrylate, styrene, tert-butylstyrene, and 3-methacryloxypropyl-tris(trimethylsiloxy) silane,  
 (B<sub>2</sub>) 5 to 35% by weight of a monomer selected from the group consisting of acrylic acid, methacrylic acid, N,N-dimethylacrylamide, and maleic anhydride, and  
 (B<sub>3</sub>) 0 to 20% by weight of ethylene glycol dimethacrylate or neopentyl glycol diacrylate, or bis-(3-methacryloxy propyl)-tetramethyl-disiloxane.

For preparing soft copolymers, such as soft contact lenses with low water absorption, the preferred polymer comprises the crosslinked, copolymerization product of (A) 30 to 80% by weight of a polysiloxane macromer of formula A1, and (B) 70 to 20% by weight of a mixture of comonomers of which, based on the total weight of comonomers, is (B<sub>1</sub>) 100 to 89% by weight of a water-insoluble monoolefinic monomer or mixture thereof, (B<sub>2</sub>) 0 to 10% by weight of a water-soluble monoolefinic monomer or mixture thereof, and (B<sub>3</sub>) 0 to 1 % by weight of a diolefinic monomer.

For making soft copolymers, such as soft contact lenses, the preferred water-insoluble monomers are methyl acrylate, ethyl acrylate or methacrylate, n-butyl acrylate or methacrylate, n-hexyl acrylate or methacrylate, 2-ethylhexyl acrylate or methacrylate, n-octyl acrylate or methacrylate, n-decyl acrylate, 2-methoxyethyl-2-ethoxyethyl-acrylate and methacrylate, 2-methoxyethyl-, 2-ethoxyethyl acrylate and methacrylate, and oligosiloxanyl alkyl methacrylates having 3 to 8 silicon atoms, like tris-(trimethyl siloxanyl)-silyl-propyl-methacrylate, and R<sub>f</sub>-alkylene acrylates and methacrylates, where R<sub>f</sub> is a perfluoroalkyl group with 1 to 10 carbon atoms and alkylene is alkylene with 1 to 5 carbon atoms.

For preparing hydrogels, for instance for hydrogel contact lenses, the preferred polymer comprises the crosslinked copolymerization product of 20 to 60% by weight of a polysiloxane macromer of formula A1 and 40 to 80% by weight of a mixture of comonomers of which, based on the total weight of comonomers, is (B<sub>1</sub>) 100 to 89% by weight of a water-insoluble monoolefinic monomer or mixture thereof, (B<sub>2</sub>) 0 to 10% by weight of a water-soluble monoolefinic monomer or mixture thereof, and (B<sub>3</sub>) 0 to 1 % by weight of a diolefinic monomer.

and (B) 80 to 40% by weight of a mixture of comonomers of which, based on the total weight of comonomers, is (B<sub>1</sub>) 0 to 30% by weight of a water-insoluble monoolefinic monomer or mixture thereof, (B<sub>2</sub>) 100 to 69% by weight of a water-soluble monoolefinic monomer or mixture thereof, and (B<sub>3</sub>) 0 to 1% by weight of a diolefinic monomer.

5 The preferred water-soluble monomers are N,N-dimethylacrylamide, N-vinyl-2-pyrrolidone, 2-hydroxyethyl methacrylate, acrylamide or mixtures thereof.

The polysiloxane-copolymers of this invention may also be treated by any of the commonly used methods used to increase the wettability of hydrophobic surfaces, such as plasma-treatment and irradiation-grafting and oxidation.

10 The contact lenses made from the polymers of this invention are hydrolytically stable, biologically inert, transparent and sufficiently permeable to oxygen to allow the transport of oxygen sufficient to meet the requirements of the human cornea.

The following examples are presented for the purpose of illustration only and are not to be construed to limit the nature and scope of the instant invention in any manner whatsoever.

15 In the following examples, specific oxygen permeability (O<sub>2</sub>-DK) is determined by measuring dissolved oxygen permeability at indicated temperatures and thickness with a CREATECH PERMEOMETER, using a polarographic electrode in an air-saturated aqueous environment and is expressed in units:

$$20 \quad O_2DK = \frac{\text{cm}^3 \text{ (STP)} \times \text{cm}}{\text{cm}^2 \times \text{sec} \times \text{cmHg}} \quad 10^{10} \text{ (barrers)}$$

25 As reference materials for O<sub>2</sub>-DK measurements, water swollen poly(2-hydroxyethyl methacrylate) (poly-hema; 39% water content; a common soft-lens material) and CAB, cellulose-acetate-butyrate (an oxygen-permeable hard-lens material) are used; for hardness CAB and poly(methyl methacrylate) are used as reference materials. The O<sub>2</sub>-DK, Shore-D and contact angle values for these materials are given below.

Hardness is determined using a Shore-D durometer on polished surfaces of center cut buttons of 10 mm diameter and 8 mm height.

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Reference Material	O <sub>2</sub> -DK	Shore-D
	(at 0.25 mm/23°C)	
poly-hema (39 % H <sub>2</sub> O)	6.5	-
poly(methyl methacrylate)	<0.1	92
40 cellulose-acetate-butyrate	8.2	80

The following examples describe the synthesis of vinyl-urea capped polysiloxanes.

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#### Example 1:

56.62 g (32.1 mmol) of an  $\alpha,\omega$ -di-propylamino-poly-(dimethylsiloxane) of 1770 MW (Shin Etsu Corp. No. X-22-161A) are placed in a 100 ml 3-neck round bottom flask fitted with a mechanical stirrer, gas inlet tube and thermometer. The diamine is cooled with an ice-water bath and kept under a dry air atmosphere. 9.97 g (64.3 mmol) 2-isocyanatoethyl methacrylate (IEM) are added and the mixture is stirred. After 30 minutes the ice-water bath is removed and the contents are stirred for an additional 4 hours. IR-analysis of the clear, light-yellow viscous liquid shows no NCO peak present ( $\sim 2350 \text{ cm}^{-1}$ ).

#### Example 2:

58.52 g (32.0 mmol) of the aminopropyl-capped PDMS of example 1 are placed in a 100 ml 3-neck round bottom flask fitted with a mechanical stirrer, gas inlet tube and thermometer. The diamine is cooled with an ice-

water bath and kept under a dry air atmosphere. 12.90 g (64.1 mmol) of m-isopropenyl- $\alpha,\alpha$ -dimethylbenzyl isocyanate (TMI) are added while stirring. After 2 hours the mixture becomes very thick and 69.42 g of trimethylcyclohexyl methacrylate (TMMA) are added. The ice-water bath is removed and the contents are stirred for an additional 4 hours to yield a 66.1% solution of  $\alpha$ -methylstyrene capped poly(dimethylsiloxane) in TMMA.

#### Example 3:

49.87 g (83.2 m equiv.) of a poly-(dimethylsiloxane) having pendant groups  $-\text{CH}_2\text{CH}_2\text{CH}_2\text{NHCH}_2\text{CH}_2\text{NH}_2$  and MW 1200 (SWS-Silicones No. F-756) are placed in a 100 ml 3-neck round bottom flask fitted with a mechanical stirrer, gas inlet tube and thermometer. The contents are cooled with an ice-water bath and kept under a dry air atmosphere. 16.70 g (82.9 mmol) of m-isopropenyl- $\alpha,\alpha$ -dimethylbenzyl isocyanate (TMI) are added while stirring. The mixture becomes viscous after 5 minutes and 33.36 g trimethylcyclohexyl methacrylate (TMMA) are added. The contents are stirred for an additional 3 hours to yield a  $\alpha$ -methylstyrenic PDMS as a 66% solution in TMMA.

#### Example 4:

48.24 g (80.4 m equiv. amine) of the poly-amino-poly(dimethylsiloxane) of example 3 are placed in a 100 ml 3-neck round bottom flask fitted with a mechanical stirrer, gas inlet tube and thermometer. The amine is cooled with an ice-water bath and kept under a dry air atmosphere. 12.48 g (80.4 mmol) of 2-isocyanatoethyl methacrylate (IEM) are added and the mixture is stirred. After 5 minutes the mixture becomes viscous and 30.67 g TMMA are added. The ice-water bath is removed and the contents are stirred for an additional 3 hours under dry air, to yield a methacrylate functional PDMS as a 66% solution in TMMA.

The following examples describe the synthesis of Polysiloxane-Hydrogels

#### Example 5 :

5.76 g (3.52 mmol) of an  $\alpha,\omega$ -di-propylamino-poly-(dimethylsiloxane) of 1636 MW (Shin Etsu Corp. No. X-22-161A) and 7.18 g N,N-dimethylacrylamide are placed in a one ounce jar and stirred, forming a cloudy mixture. The mixture is cooled in an ice-water bath and 1.50 g (7.45 mmol) of m-isopropenyl- $\alpha,\alpha$ -dimethylbenzyl isocyanate (TMI) added. The solution turns clear and is stirred for 2 hours. 0.29 g Benzoin methyl ether (BME) are added and dissolved. The mixture is degassed by applying vacuum and sparged with nitrogen (3 cycles), then is poured into a MYLAR-lined glass mold, held together by clamps and using 0.5 mm thick silicone cord as spacer. The mold is exposed to UV light from a SYLVANIA Blacklite-Blue fluorescent lamp for 4 hours, after which time the mold is opened and the clear, stiff polymer sheet is removed. It is cut into rectangular pieces for testing. After equilibration in distilled water, hydrogels with an equilibrium water content of 25.4% are obtained.

#### Example 6:

Using the procedure described in example 5, but using instead of TMI the equivalent amount of 2-isocyanatoethyl methacrylate (IEM), clear hydrogels are prepared, having an equilibrium water content of 25.8%.

#### Example 6a:

Cut strips of polymer from example 5 and 6 are immersed for 5 days at 80°C in aqueous base of different pH and the change in water content is determined after subsequent re-equilibration in water at pH = 7. The results are shown below:

Polymer of Example	Equilibrium Swelling in Water (%) <sup>1)</sup>			
	Initial	After 5 days/80°C		24 days/80°C
		at pH = 14	at pH = 10	at pH 10
5	25.4	73	50	52
6	25.8	disintegrated	59	72

<sup>1)</sup>  $\frac{\text{wet weight} - \text{dry weight}}{\text{wet weight}} \times 100$

The urea-styryl based PDMS-hydrogel of example 5 is considerably more resistant to base catalyzed hydrolysis than the urea-methacrylate analog of example 6.

The following examples describe the synthesis of chain extended macromers.

#### Example 7:

9.045 g (5.53 m equiv. amine) of an  $\alpha,\omega$ -di-propylamino-poly-(dimethylsiloxane) of MW 1636 (Shin Etsu Corp. No. X-22-161 A) are placed in a 1 oz. jar; 4.56 g of hexafluoroisopropyl methacrylate (F<sub>6</sub>MA) are added and the mixture is stirred and cooled in an ice-water bath. 0.21 g (0.9546 mmol) of isophorone diisocyanate (IPDI) are added and the mixture is stirred for 2 hours at room temperature until all isocyanate has disappeared (by IR). Then 1.85 g (9.22 mmol) m-isopropenyl- $\alpha,\alpha$ -dimethylbenzylisocyanate (TMI) are added and the mixture is stirred for 2 more hours to yield a clear viscous liquid of a 70.90% solution of  $\alpha$ -methyl styrene capped, chain extended poly(dimethylsiloxane) of MW 2426 (calculated) in F<sub>6</sub>MA.

#### Examples 8-10:

The procedure of example 7 is repeated, but using the molar ratios of  $\alpha,\omega$ -di-propylamino-poly-(dimethylsiloxane) to IPDI as listed below:

Example #	Mol Ratio of Diamine to IPDI	Calculated MW after Capping with equiv. TMI
7	6:1	2426
8	4:1	2693
9	2:1	4023
10	3:2	6019

#### Example 11:

Using the PDMS-macromer mixture of example 2, a solution is prepared in a 100 ml jar which contains 30 g of the  $\alpha$ -methylstyrene capped poly(dimethyl siloxane) macromer described in example 2, 18 g trimethylcyclohexyl methacrylate (TMMA), 28 g hexafluoroisopropyl methacrylate (F<sub>6</sub>MA), 9 g methacrylic acid (MAA) and 15 g ethylene glycol dimethacrylate (EDMA); 0.24 g BME are added and dissolved and the clear solution is degassed in vacuo and sparged with nitrogen.

The solution is filled into round polypropylene molds of 1 cm height and 9 mm diameter, which are placed into the openings of a flat tray. The polymerization is carried out in a box sparged with nitrogen by exposure to UV light from a SYLVANIA-Blacklite Blue fluorescent lamp for seven hours. Following removal of the molds from the boxes, the buttons are annealed at 100°C for 1 hour, cooled to room temperature and pressed out of

the mold. The clear buttons are cut into slices of appropriate thickness on a bone saw for measuring hardness and oxygen permeability.

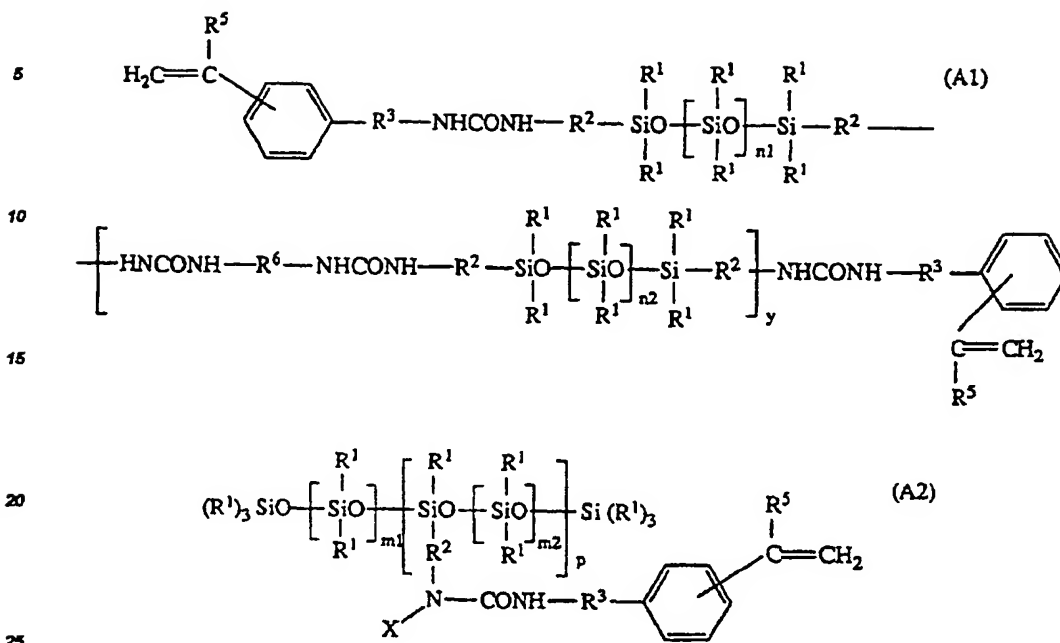
Examples 12-22:

Example 11 is repeated, but with compositions listed in the table below; all compositions contain 28% F<sub>6</sub>MA and 9% MAA. All polymers are tested as described.

Example No.	Composition			Hardness Shore-D)	Oxygen Permeability O <sub>2</sub> DK (barrers) at 0.25 mm/21°C
	Macromer of Ex.	TMMA %	EDMA %		
12	7	40	8	15	72
13	7	45	3	15	68
14	8	40	8	15	72
15	8	45	3	15	68
16	9	40	8	15	71
17	9	45	3	15	67
18	10	40	8	15	70
19	10	45	3	15	66
20	2	40	8	15	71
21	2	45	3	15	69
22	2	40	3	20	65

**Claims**

1. A polysiloxane-urea styrenic macromer of the structure A1 or A2



wherein, independently of each other,

$\text{R}^1$  is methyl, phenyl or 3,3,3-trifluoropropyl,

$\text{R}^2$  is a divalent saturated linear or branched hydrocarbon radical having 1 to 6 carbon atoms,

$\text{R}^3$  is a direct bond or has the same definition as  $\text{R}^2$ ,

$\text{R}^5$  is hydrogen or methyl,

$\text{R}^6$  is the divalent residue of an aliphatic, cycloaliphatic or aromatic diisocyanate of structure



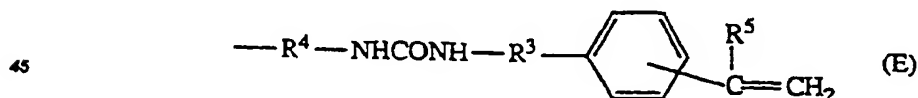
$n1$  and  $n2$  are integers from 2 to 250, with the proviso that the sum  $n1 + n2$  is not greater than 250,

$m1$  and  $m2$  are integers from 2 to 200, with the proviso that the sum  $m1 + m2$  is not greater than 250,

$y$  is 0 to 2,

$p$  has a value of 1 to 10,

$\text{X}$  is hydrogen or has the structure E:



wherein  $\text{R}^4$  is a divalent saturated linear or branched hydrocarbon radical having 1 to 6 carbon atoms.

50 2. A macromer according to claim 1 of structure A1, in which

$\text{R}^1$  is methyl,

$\text{R}^2$  is trimethylene,

$\text{R}^3$  is  $-\text{C}(\text{CH}_3)_2-$

$\text{R}^6$  is methyl,

55  $y$  is zero, and

$n1$  is 5 to 100.

3. A macromer according to claim 1 of structure A1, in which

R<sup>1</sup> is methyl,  
 R<sup>2</sup> is trimethylene,  
 R<sup>3</sup> is -C(CH<sub>3</sub>)<sub>2</sub>-  
 R<sup>5</sup> is methyl,

6 y is 1,

n<sub>1</sub> + n<sub>2</sub> is 10 to 20, and R<sup>6</sup> is an aliphatic or aromatic divalent residue with 6 to 12 carbon atoms.

4. A macromer according to claim 1 of structure A2, wherein

10 R<sup>1</sup> is methyl,  
 R<sup>2</sup> is trimethylene,  
 R<sup>3</sup> is -C(CH<sub>3</sub>)<sub>2</sub>-  
 R<sup>5</sup> is methyl,  
 X is of structure E,  
 R<sup>4</sup> is ethylene,

15 m<sub>1</sub> and m<sub>2</sub> are 5 to 100, with the sum of m<sub>1</sub> + m<sub>2</sub> not greater than 150,  
 and p is 1 to 3.

5. A macromer according to claim 2 of structure A1, wherein n<sub>1</sub> is 10 to 50.

- 20 6. A macromer according to claim 1 wherein R<sup>3</sup> is a direct bond and R<sup>5</sup> is hydrogen with the -CR<sup>5</sup>=CH<sub>2</sub> group being in the para position relevant to R<sup>3</sup>; or wherein R<sup>3</sup> is -C(CH<sub>3</sub>)<sub>2</sub>- and R<sup>5</sup> is methyl with the -CR<sup>5</sup>=CH<sub>2</sub> group being in the meta position relevant to R<sup>3</sup>.

- 25 7. A macromer according to claim 1 wherein R<sup>6</sup> is derived from a diisocyanate of formula OCN-R<sup>6</sup>-NCO which is selected from the group consisting of ethylene diisocyanate, 1,2-diisocyanatopropane, 1,3-diisocyanatopropane, 1,6-diisocyanatohexane, 1,2-diisocyanatocyclohexane, 1,3-diisocyanatocyclohexane, 1,4-diisocyanatobenzene; bis-(4-isocyanatophenyl)methane, 1,2- and 1,4-toluene diisocyanate; 3,3'-dichloro-4,4'-diisocyanatobiphenyl; 1,5-diisocyanatonaphthalene, hydrogenated toluene diisocyanate; 1-isocyanatomethyl-5-isocyanato-1,3,3-trimethylcyclohexane (= isophorone diisocyanate); 1,6-diisocyanato-2,2,4-(2,4,4)-trimethylhexane, 2,2'-diisocyanatodiethyl fumarate; 1,5-diisocyanato-1-carboxypentane; 1,2-, 1,3-, 1,6-, 1,7-, 1,8-, 2,7- and 2,3-diisocyanatonaphthalene; 2,4- and 2,7-diisocyanato-1-methylnaphthalene; 1,4-diisocyanato-methylcyclohexane; 1,3-diisocyanato-6(7)-methylnaphthalene; 4,4'-diisocyanatobiphenyl; 4,4'-diisocyanato-3,3'-dimethoxy-biphenyl; 3,3'- and 4,4'-diisocyanato-2,2'-dimethyl-biphenyl; bis-(4-isocyanatophenyl)ethane; bis(4-isocyanato-phenyl) ether.

- 35 8. A macromer according to claim 7 wherein the diisocyanate is isophorone diisocyanate, 2,2,4-(2,4,4)-trimethylhexane-1,6-diisocyanate or 1,2- or 1,4-toluene diisocyanate.

- 40 9. A polymer, suitable as a biocompatible, oxygen permeable polymer, useful for preparing contact lenses which comprises the crosslinked copolymerization product of

(A) from about 10 to about 100% by weight of said polymer of a polysiloxane macromer of formula A1 or A2 according to claim 1, having a molecular weight from about 400 to about 10,000, said macromer containing at least two terminal polymerizable olefinic groups, said groups being attached to the polysiloxane through a urea linkage, and

45 (B) from 90% to 0% by weight of said polymer of one or more mono-, di- or trifunctional vinyl monomers polymerizable by free radical polymerization.

10. A polymer according to claim 9 which comprises the crosslinked copolymerization product of

50 (A) from about 15 to about 90% by weight of said polymer of a polysiloxane macromer having a molecular weight from about 800 to about 10,000, said macromer containing two terminal, polymerizable olefinic groups, said macromer having the structure of formula A1 or A2, and

(B) from about 85 to about 10 % by weight of said polymer of water-soluble or water-insoluble monomers or mixtures thereof, said monomers being monoolefinic, diolefinic or a mixture of monoolefinic and diolefinic monomers.

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11. A polymer according to claim 9 for preparing hard contact lenses which comprises the crosslinked copolymerization product of (A) from 15 to 80% of a polysiloxane macromer of formula A1 or A2, and (B) from 85 to 20% by weight of a mixture of comonomers of which, based on the total weight of comonomers, is (B<sub>1</sub>)

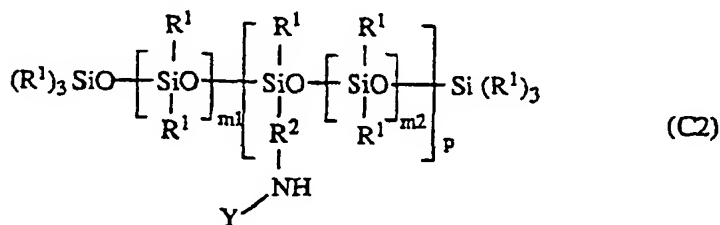
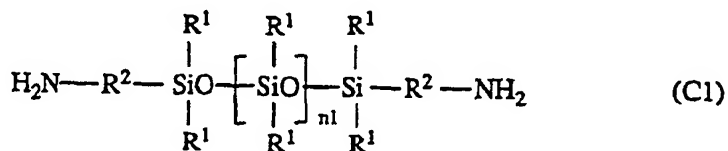
100 to 65% by weight of a water-insoluble monoolefinic monomers or mixtures thereof, (B<sub>2</sub>) 0 to 35% by weight of a water-soluble monoolefinic monomer or mixture thereof, and (B<sub>3</sub>) 0 to 35% by weight of a diolefinic monomer.

- 5 12. A polymer according to claim 11 wherein B<sub>1</sub> is methyl methacrylate, cyclohexyl methacrylate, tris(trimethyl-siloxy)silyl-propyl methacrylate, 2,2,2-trifluoroethyl methacrylate, hexafluoroisopropyl methacrylate, 1,1-dihydroheptafluorobutylmethacrylate, trimethylcyclohexyl methacrylate, isobomyl methacrylate, tert-butyl methacrylate, tert-butyl-styrene or mixtures thereof; B<sub>2</sub> is 2-hydroxyethyl methacrylate, N,N-dimethylacrylamide, acrylic acid, methacrylic acid, maleic anhydride or N-vinyl-2-pyrrolidone or mixtures thereof; and B<sub>3</sub> is ethylene glycol dimethacrylate, neopentyl glycol diacrylate or methacrylate, and bis-(3-methacryloxy propyl) tetramethyl disiloxane or bis (3-methacryloxypropyl) tetra (trimethylsiloxy) disiloxane.
- 10 13. A polymer according to claim 11 which comprises the copolymerization product of  
(A) 20 to 75% by weight of a polysiloxane of formula A1 where R<sup>1</sup> and R<sup>5</sup> are methyl, R<sup>2</sup> is trimethylene, R<sup>3</sup> is -C(CH<sub>3</sub>)<sub>2</sub>-, and n1 is 10 to 50, and  
15 (B) 80 to 25% by weight of a mixture of comonomers of which, based on the total weight of comonomers, is  
(B<sub>1</sub>) 95 to 65% by weight of a water-insoluble monoolefinic monomer or mixture thereof, and  
(B<sub>2</sub>) 5 to 35% by weight of a water-soluble monoolefinic monomer or mixture thereof.
- 20 14. A polymer according to claim 11 which comprises the copolymerization product of  
(A) 20 to 75% by weight of a polysiloxane of formula A1 where R<sup>1</sup> and R<sup>5</sup> are methyl, R<sup>2</sup> is trimethylene, R<sup>3</sup> is -C(CH<sub>3</sub>)<sub>2</sub>-, n1 is 10 to 50, y is 1, and, R<sup>6</sup> is the divalent residue of isophorone diisocyanate; 2,2,4-(2,4,4)- trimethylhexane-1,6-diisocyanate or toluene diisocyanate; and  
25 (B) 80 to 25% by weight of comonomers of which, based on the total weight of comonomers, is  
(B<sub>1</sub>) 95 to 65% by weight of a water-insoluble monoolefinic monomer or mixture thereof,  
(B<sub>2</sub>) 5 to 35% by weight of a water-soluble monoolefinic monomer or mixture thereof, and  
(B<sub>3</sub>) 0 to 20% by weight of a diolefinic monomer.
- 30 15. A polymer according to claim 11 which comprises the copolymerization product of  
(A) 20 to 75% by weight of a polysiloxane of formula A1 where R<sup>1</sup> is methyl, and  
(B) 80 to 25% by weight of a mixture of comonomers of which, based on the total weight of comonomers, is  
35 (B<sub>1</sub>) 95 to 65% by weight of a monomer selected from the group consisting of methyl methacrylate, cyclohexyl methacrylate, trimethylcyclohexyl methacrylate, isobomyl methacrylate, 2,2,2-trifluoroethyl methacrylate, hexafluoroisopropyl methacrylate, 1,1-dihydroheptafluorobutyl methacrylate, tris(trimethylsiloxy-silyl)propyl methacrylate, tert-butyl methacrylate, styrene and tert-butylstyrene,  
(B<sub>2</sub>) 5 to 35% by weight of a monomer selected from the group consisting of acrylic acid, methacrylic acid, N,N-dimethylacrylamide, and maleic anhydride,  
40 (B<sub>3</sub>) 0 to 20% by weight of ethylene glycol dimethacrylate, neopentyl glycol diacrylate, or bis-(3-methacryloxypropyl)-tetramethyl-disiloxane.
16. A polymer according to claim 11 which comprises the copolymerization product of  
(A) 20 to 75% by weight of a polysiloxane of formula A2 where R<sup>1</sup> and R<sup>5</sup> are methyl, R<sup>2</sup> is trimethylene, R<sup>3</sup> is -C(CH<sub>3</sub>)<sub>2</sub>-, X is of structure (E), R<sup>4</sup> is ethylene, n1 is 10 to 50, p is 1 to 3, and  
45 (B) 80 to 25% by weight of a mixture of comonomers of which, based on the total weight of comonomers, is  
(B<sub>1</sub>) 95 to 65 % by weight of a monomer selected from the group consisting of methyl methacrylate, cyclohexyl methacrylate, trimethylcyclohexyl methacrylate, isobomyl methacrylate, 2,2,2-trifluoroethyl methacrylate, hexafluoroisopropyl methacrylate, 1,1-dihydroheptafluorobutyl methacrylate, tert-butyl methacrylate, styrene, tert-butylstyrene, and 3-methacryloxypropyl-tris(trimethylsiloxy)silane,  
50 (B<sub>2</sub>) 5 to 35% by weight of a monomer selected from the group consisting of acrylic acid, methacrylic acid, N,N-dimethylacrylamide, and maleic anhydride, and  
(B<sub>3</sub>) 0 to 20% by weight of ethylene glycol dimethacrylate or neopentyl glycol diacrylate, or bis-(3-methacryloxy propyl)-tetramethyl-disiloxane.
- 55 17. A polymer according to claim 9 for soft contact lenses with 1 w water absorption, which comprises the crosslinked, copolymerization product of (A) 30 to 80% by weight of a polysiloxane macromer of formula

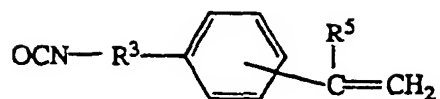


A1, and (B) 70 to 20 by weight of a mixture of comonomers of which, based on the total weight of comonomers, is (B<sub>1</sub>) 100 to 89% by weight of a water-insoluble monoolefinic monomer or mixture thereof, (B<sub>2</sub>) 0 to 10% by weight of a water-soluble monoolefinic monomer or mixture thereof, and (B<sub>3</sub>) 0 to 1% by weight of a diolefinic monomer.

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18. A polymer according to claim 17 wherein B<sub>1</sub> is selected from the group consisting of methyl acrylate, ethyl acrylate or methacrylate, n-butyl acrylate or methacrylate, n-hexyl acrylate or methacrylate, 2-ethylhexyl acrylate or methacrylate, n-octyl acrylate or methacrylate, n-decyl acrylate, 2-methoxyethyl-2-ethoxyethyl-acrylate and methacrylate, 2-methoxyethyl-, 2-ethoxyethyl acrylate and methacrylate, oligo-siloxanyl alkyl methacrylates having 3 to 8 silicon atoms, and R<sub>4</sub>-alkylene acrylates and methacrylates, where R<sub>4</sub> is a perfluoroalkyl group with 1 to 10 carbon atoms and alkylene is alkylene with 1 to 5 carbon atoms, and mixture thereof.
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19. A polymer according to claim 9 wherein the polymer comprises the crosslinked copolymerization product of (A) 20 to 60% by weight of a polysiloxane macromer of formula A1 or A2 and (B) 80 to 40 by weight of a mixture of comonomers of which, based on the the total weight of comonomers, is (B<sub>1</sub>) 0 to 30% by weight of a water-insoluble monoolefinic monomer or mixture thereof, (B<sub>2</sub>) 100 to 69% by weight of a water-soluble monoolefinic monomer or mixture thereof, and (B<sub>3</sub>) 0 to 1% by weight of a diolefinic monomer.
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20. A polymer according to claim 19, wherein component B<sub>2</sub> is N,N-dimethylacrylamide, N-vinyl-2-pyrrolidone, 2-hydroxyethyl methacrylate, acrylamide or a mixture thereof.
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21. A polymer according to claim 9, in form of a contact lens.
22. A polymer according to claim 11, in form of a contact lens.
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23. A polymer according to any of claims 9 to 20, in form of a contact lens.
24. A contact lens comprising a polymer according to any of claims 9 to 20.
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25. A contact lens consisting essentially of a polymer according to any of claims 9 to 20.
26. A process for the manufacture of a macromer according to claim 1 comprising conventionally reacting a compound of formula C1 or C2
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wherein Y is hydrogen or -R<sup>4</sup>NH<sub>2</sub> and all the other variables are as defined in claim 1, with a styrene-isocyanat of structure



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wherein the variables are as defined in claim 1, preferably in equivalent amounts; wherein a compound of formula C1, if desired, is reacted with a diisocyanate of structure  $\text{OCN}-\text{R}^6-\text{NCO}$ , wherein  $\text{R}^6$  is as defined in claim 1, before the reaction of said compound of formula C1 with said styrene-isocyanate.

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27. A process for the manufacture of a polymer according to claim 9 by conventionally copolymerizing a macromer of formula A1 or A2 as defined in claim 1 with the vinyl monomers B as defined in claim 9.

28. Use of a polymer of claim 9 for the manufacture of a contact lens.

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## EUROPEAN SEARCH REPORT

Application Number

DOCUMENTS CONSIDERED TO BE RELEVANT			EP 91810291.4
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
D, A	<u>US - A - 4 605 712</u> (MUELLER et al.) * Examples 19,10; examples 22-42; claims 1,5-19 * ---	1, 9-12, 15, 17-28	C 08 G 77/388 C 08 G 77/26 C 08 G 77/458 C 08 F 283/12 G 02 B 1/04
A	<u>EP - A2 - 0 186 424</u> (DOW CORNING CORPORATION) * Claims; example 1 * & US-A-4 563 539 ---	1,26, 27	
D			
A	<u>EP - A2 - 0 274 699</u> (WACKER SILICONES CORPORATION) * Column 10, line 16 - column 13; line 38; claims 1-4,10; column 9, lines 21-45 * ---	1, 9-12, 26,27	
A	<u>US - A - 4 594 401</u> (TAKAHASHI et al.) * Claims 1,6-13; column 3, line 56 - column 5, line 51 * -----	1, 9-12, 15, 17-25	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)  C 08 G 77/00 C 08 F 283/00 G 02 B
The present search report has been drawn up for all claims			
Place of search	Date of completion of the search	Examiner	
VIENNA	09-08-1991	KALTENEGER	
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons  A : member of the same patent family, corresponding document	
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			

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